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Geophysical, petrological and mineral physics constraints on Earth's surface topography

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Earth's surface topography is controlled by isostatically compensated density variations within the lithosphere, but dynamic topography - i.e. the topography due to adjustment of surface to mantle convection - is an important component, specially at a global scale. In order to separate these two components it is fundamental to estimate crustal and mantle density structure and rheological properties.

Usually, crustal density is constrained from interpretation of available seismic data (mostly VP profiles) based on empirical relationships such those in Brocher [2005]. Mantle density structure is inferred from seismic tomography models. Constant coefficients are used to interpret seismic velocity anomalies in density anomalies. These simplified methods are unable to model the effects that pressure and temperature variations have on mineralogical assemblage and physical properties.

Our approach is based on a multidisciplinary method that involves geophysical observables, mineral physics constraints, and petrological data. Mantle density is based on the thermal interpretation of global seismic tomography models assuming various compositional structures, as in Cammarano et al. [2011]. We further constrain the top 150 km by including heat-flow data and considering the thermal evolution of the oceanic lithosphere. Crustal density is calculated as in Guerri and Cammarano [2015] performing thermodynamic modeling of various average chemical compositions proposed for the crust. The modeling, performed with the code *Perple_X* [Connolly, 2005], relies on the thermodynamic dataset from Holland and Powell [1998]. Compressional waves velocity and crustal layers thickness from the model CRUST 1.0 [Laske et al., 2013] offer additional constraints. The resulting lithospheric density models are tested against gravity (GOCE) data.

Various crustal and mantle density models have been tested in order to ascertain the effects that uncertainties in the estimate of those features have on the modeled topography. We also test several viscosity models, either radially symmetric, the V1 profile from Mitrova and Forte [2004], or more complex laterally varying structures.

All the property fields are expanded in spherical harmonics, until degree 24, and implemented in the code *StagYY* [Tackley, 2008] to perform mantle instantaneous flow modeling and compute surface topography and gravitational field.

Our results show the importance of constraining the crustal and mantle density structure relying on a multidisciplinary approach that involves experimentally robust thermodynamic datasets. Crustal density field has a strong effect on the isostatic component of topography. The models that we test, CRUST 1.0 and those in Guerri and Cammarano [2015], produce strong differences in the computed isostatic topography, in the range ± 600 m. For the lithospheric mantle, relying on experimentally robust material properties constraints is necessary to infer a reliable density model that takes into account chemical heterogeneities. This approach is also fundamental to correctly interpret seismic models in temperature, a crucial parameter, necessary to determine the lithosphere-asthenosphere boundary, where static effects on topography leave place to dynamic ones.

The comparison between results obtained with different viscosity fields, either radially symmetric or vertically and laterally varying, shows how lateral viscosity variations affect the results, in particular the modeled geoid, at different wavelengths.

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